in water from the shallower well than from the deeper well. In sec. 9, T. 10 N., R. 3 W., the water from the deeper well contained larger concentrations of dissolved constituents than water from the shallower well. In some instances, differences may be attributable to improper sample collection, but mostly the differences indicate that the shallower ground waters have been altered by some activity of man. However, all the samples were of acceptable quality for drinking water with respect to the constituents and properties analyzed and measured.

On-site measurements

On-site measurements were made of specific conductance and nitrate in water samples from the test wells and from 98 domestic wells located throughout the valley. The results aid in definition of the areal distribution of water quality.

Specific conductance

Specific conductance is a measure of the capability of water to conduct an electrical current. It is directly related to the amount of dissolved constituents contained in the water. Although no unique relationship exists for waters containing different ratios and concentrations of ions, an empirical relation between specific conductance and the concentration of dissolved solids was developed for the study area. Within a range of specific conductance from about 200 to 1,500 µmho/cm (micromhos per centimeter at 25° Celsius), the concentration of dissolved solids can be estimated (fig. 5) using the linear equation:

$$DS = [0.65 \times SC] - 15 \tag{1}$$

where DS = dissolved-solids concentration, in milligrams per liter; and

SC = specific conductance, in micromhos per centimeter at 25° Celsius

The range of values of specific conductance plotted on plate 4 illustrates the variability of water quality throughout the area. The data represent the aquifers from which most of the domestic supplies in the valley are obtained, although variations with depth generally are unknown.

Most wells on the east side of the valley contain water having a specific conductance of less than 400 µmho/cm (dissolved solids of less than 245 mg/L). Larger values of specific conductance in an area southeast of Lake Helena and northwest of the Helena Valley Regulating Reservoir probably are related to agricultural activities.

Specific conductance is larger in the southwestern part of the valley. In sec. 16, T. 10 N., R. 3 W., specific conductance greater than 1,600 µmho/cm was measured in water from a test well near the Helena municipal wastewater treatment facility. Another test well in sec. 17, T. 10 N., R. 3 W., yielded

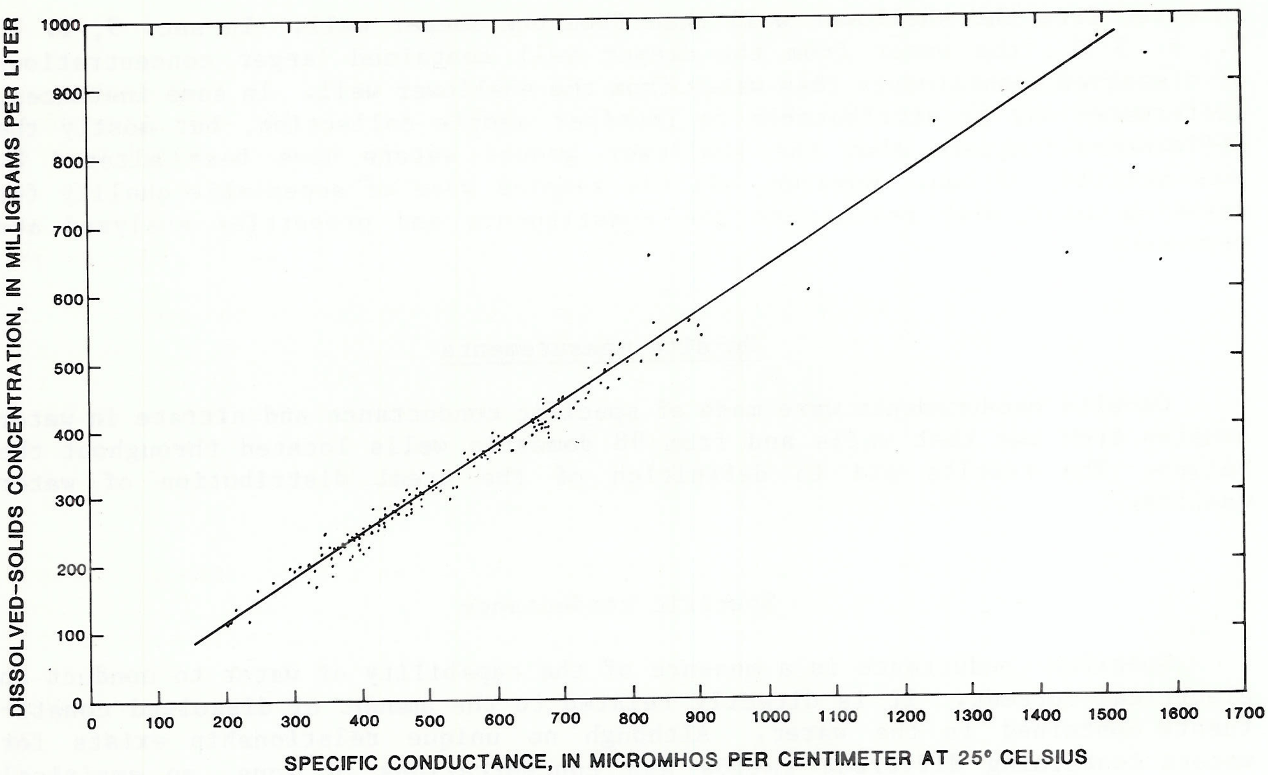

Figure 5.--Relation of specific conductance to dissolved solids in Helena Valley ground water.

a sample having a specific conductance of greater than 1,500 µmho/cm. This well is located near the old landfill site, which has recently been used as a burial site for sludge from the wastewater treatment facility. Other large values of specific conductance for samples collected in secs. 8, 17, and 18, T. 10 N., R. 3 W., probably are related to the dredge operations previously described. The specific conductance of water from several wells near the Scratchgravel solid waste disposal site in sec. 12, T. 10 N., R. 4 W., exceeds 600 µmho/cm. Leaching of waste is the probable cause of the large values.

Most of the samples from wells in the northwestern part of the valley had specific conductance in excess of 500 µmho/cm. Agricultural activity and domestic sewage from septic tanks probably are the sources of the larger than average values in this area.

Other isolated occurrences of larger than average specific conductance shown on plate 4 may be related to local agricultural activities. Insufficient data are available to determine the specific sources of the large values.

Nitrate concentrations

The concentration of nitrate (by convention expressed in milligrams per liter as nitrogen) commonly is used as an indicator of contamination from sewage effluent. Although sewage effluent normally contains more than 1 mg/L of nitrate, it is not the only source of nitrate in ground water. Pristine ground water generally contains less than 0.1 mg/L of nitrate. Where nitrate occurs in excess of 0.1 mg/L, some man-related activity is probably the cause.

Agricultural activities are commonly the source of nitrate in ground water. Plowing virgin land and replacing deep-rooted native vegetation with shallower-rooted crops can mobilize nitrate, which has historically been held in the soil zone. Excessive application of nitrogen-based fertilizers can contribute large amounts of nitrate to underlying ground waters. Animal wastes, particularly where concentrated in feedlots, corrals, or barnyards, can also contribute to the nitrate load.

The U.S. Environmental Protection Agency (1976) has placed a maximum allowable limit of 10 mg/L on nitrate in community water supplies. Studies have indicated that serious and occasionally fatal poisoning in infants has occurred following ingestion of well water containing more than 10 mg/L of nitrate. Although only infants appear to be susceptible to nitrate poisoning at this concentration, sufficient evidence exists to place the mandating limit on public water supplies.

The distribution of nitrate in samples collected during this study is shown on plate 5. Virtually all samples contained concentrations of nitrate in excess of 0.1 mg/L, but samples from only two test wells contained nitrate at concentrations exceeding the maximum limit of 10 mg/L. A sample collected on April 11, 1979, from test well 10N03W17ACAD01 located near the old landfill site, contained 52 mg/L of nitrate. A sample collected on January 19, 1979, from test well 10N03W11DDCC01 in a largely undeveloped area contained 12 mg/L of nitrate, but a sample collected on April 11, 1979, contained 1.2 mg/L. The largest concentration for a domestic well was 7.6 mg/L in a sample collected on June 7, 1979, from domestic well 11N03W17DDD01.

Ground water with relatively small values of specific conductance and nitrate concentrations greater than 1.0 mg/L underlies a broad area along the eastern edge of the study area. The small specific-conductance values and relatively large nitrate concentrations indicate that fertilizer leached by irrigation water having relatively small dissolved-solids concentrations is the major source of nitrates.

Concentrations of nearly 4 mg/L of nitrate in ground water from the eastern part of sec. 18, T. 10 N., R. 3 W., further substantiates the theory that sewage used in past dredging operations has degraded the ground water in that area. Much of the water underlying the northwestern part of the study area contains more than 1.0 mg/L of nitrate. Several representative samples (sec. 31, T. 11 N., R. 3 W., and sec. 24, T. 11 N., R. 4 W.) were from wells near residential developments where septic tanks may be major contributors to the nitrate concentrations.

Long-term water-quality changes

Several wells in the Helena Valley have been sampled periodically since about 1971 to monitor changes in water quality. Concentrations of chloride and nitrate and the specific conductance of samples collected between 1971 and 1979 are listed in table 1.

In general, the records indicate that water quality has not changed radically since 1971. The specific conductance of samples from all wells except one increased with time, but annual fluctuations generally exceed the long-term variations. The specific conductance of water from wells in sec. 18, T. 10 N., R. 3 W., generally increased from 1971 through 1976, then decreased gradually through 1979. Samples from well 10N03W08CDD01, downgradient from these wells, show a continual gradual increase. The data indicate that a plume of degraded water near the old dredging operations is slowly moving northeast from section 18. Concentrations of nitrate and chloride show similar patterns.

The wells for which long-term records are available are all located in the western part of the study area and do not represent the overall water quality in the Helena Valley. Most were selected to monitor the movement of degraded water near the dredging operations. A broader network of wells would be needed to monitor changes throughout the valley.

A network of wells equally spaced throughout the valley could be sampled periodically for specific conductance and nitrate to more accurately evaluate long-term ground-water-quality changes. If significant changes in specific conductance or concentrations of nitrate were noted, more complete analyses would be justified.

SUMMARY

The Helena Valley is underlain by a thick accumulation of unconsolidated clay, silt, sand, and gravel. The coarser-grained material is the source of domestic water supplies for nearly 5,000 valley residents.

Most domestic wells in the valley are drilled through at least one layer of fine-grained material to obtain adequate yield and to avoid the potentially contaminated water in the shallowest aquifers. The layers of fine-grained material do not appear to form a continuous layer over the underlying aquifers. In parts of the valley, no layers of fine-grained material were penetrated by wells or test holes to the depths drilled. Where layers of fine-grained material were penetrated, the layers are discontinuous.

Depth to ground water varies seasonally throughout the valley. The magnitude and timing of the seasonal fluctuations are dependent upon the source of recharge. In most of the valley, water levels are highest in July or August in response to widespread irrigation. Highest water levels in a few wells located near stream channels occur during the spring in response to snowmelt runoff. High water-table conditions characterize a broad area in the northeastern part of the valley. The map showing depth to water is considered to

Table 1.--Selected chemical constituents in water from monitored wells

Well number	Date	Chloride (milligrams per liter)	Nitrite plus nitrate as N (milligrams per liter)	Specific conductance (micromhos per centimeter at 25° Celsius)
11N03W31DAD01	12-18-72	9.1	1.0	554
	08-23-73	8.6	.96	565
	12-03-74	9.4	.92	570
	01-21-76	5.8	1.0	575
	06-13-77	7.9	.5	[a]575
11N03W31DDA01	09-01-71	7.2	1.0	556
	12-18-72	10	1.2	555
	08-23-73	8.9	1.1	566
	12-03-74	9.3	.97	578
	01-21-76	5.6	1.2	577
	06-13-77	8.1	.90	[a]584
	11-06-78	4.4	[b]1.0	569
	02-20-79	10	[b].96	582
10N03W05ABA01	08-17-71	6.8	.9	418
	12-18-72	7.7	.8	435
	08-23-73	7.0	.67	430
	06-13-77	7.8	.75	[a]448
	11-06-78	6.8	[b].88	426
	02-13-79	7.7	[b].63	436
10N03W06ACD01	08-18-71	6.4	.4	487
	12-18-72	9.0	.4	503
	08-23-73	8.4	.44	506
	12-03-74	8.5	.33	507
	01-21-76	5.8	.41	496
	06-13-77	9.1	.63	[a]530
	11-06-78	9.1	[b].50	502
	02-13-79	11	[b].64	505
10N03W08BBA01	08-24-71	7.1	1.1	409
	12-18-72	10	1.4	439
	08-23-73	9.5	.83	450
	01-21-76	11	2.1	471
	06-13-77	8.8	1.4	[a]470
	11-06-78	13	[b]1.9	491
	02-13-79	10	[b]1.4	454
10N03W08CDD01	08-24-71	19	1.8	607
	12-18-72	22	1.6	641
	08-23-73	24	1.9	650
	12-03-74	22	1.3	636
	01-21-76	22	2.2	651
	06-13-77	23	2.9	[a]675
	11-06-78	27	[b]3.9	671
	02-13-79	28	[b]3.8	672

Table 1.--Selected chemical constituents in water from monitored wells--Continued

Well number	Date	Chloride (milligrams per liter)	Nitrite plus nitrate as N (milligrams per liter)	Specific conductance (micromhos per centimeter at 25° Celsius)
10N03W18ACC01	08-23-71	11	.59	528
	12-18-72	21	1.4	842
	12-03-74	20	1.5	883
	01-21-76	16	1.4	618
	06-13-77	23	1.1	[a]572
	02-13-79	19	[b]1.1	586
10N03W18ADA01	01-24-73	--	5.1	--
	08-23-73	29	4.2	734
	12-03-74	26	2.6	752
	01-21-76	25	2.8	821
	06-13-77	25	4.5	[a]820
	02-13-79	22	[b]3.7	755
10N03W18ADA02	05-19-70	23	8.0	691
	08-24-71	24	6.3	636
	12-18-72	29	15	792
	01-24-73	--	15	--
	07-05-73	22	2.4	--
	12-03-74	25	2.4	837
	01-21-76	25	2.8	862
	06-13-77	24	3.9	[a]830
	11-06-78	21	[b]4.8	781
	02-20-79	20	[b]3.5	737
10N03W18BAA01	08-23-71	25	1.3	708
	12-18-72	22	1.1	711
	12-03-74	21	1.9	667
	01-21-76	27	2.2	720
	06-13-77	34	1.7	[a]822
	11-06-78	21	[b]2.1	647
	02-13-79	25	[b]1.3	654

[a]On-site determination
[b]Nitrate only

be only a useful approximation. Test pits or borings are the only source of precise information on depth to water at specific sites.

Aquifer tests of selected wells in the valley indicate that the transmissivity of the unconsolidated material is about 1×10^4 ft^2/d. Using a water-table or potentiometric-surface gradient of 20 ft/mi, underflow through an area 1 mile wide is about 2×10^5 ft^3/d or 1,500,000 gal/d.

The aquifer tests indicate that the aquifers are overlain by leaky confining layers. A large-capacity well or a well field can be expected to produce a cone of depression that would induce downward migration of water through the leaky confining layer. However, if the pumping rate is relatively small, and the transmissivity of the aquifer is as much as 1×10^4 ft^2/day, water percolating into the aquifer from above should be significantly diluted by deeper water moving laterally toward the well.

Water quality in the aquifers underlying the valley is variable but is generally acceptable for domestic use. The water is primarily calcium bicarbonate type water containing about 400 mg/L of dissolved solids. Nitrate concentrations of water samples from domestic and test wells ranged from about 0.1 to 52 mg/L but were generally less than 2.0 mg/L. Although long-term records of water quality are available for only part of the study area, the data indicate that water quality has not changed radically since 1971. Monitored wells near the old dredging operations show that a plume of degraded water is slowly moving northeast from sec. 18, T. 10 N., R. 3 W. This study reveals the impacts of man's activities on ground-water quality in many parts of the valley. It also indicates that a network of wells throughout the valley could be used to more accurately evaluate long-term water-quality changes.

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